Informational Frictions in Decentralized Markets

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Motivation

Many large asset classes [bonds, derivatives, real estate, corporate takeovers, etc.] are traded in markets that feature:

1. bilateral transactions
   - these markets are commonly referred to as "decentralized" or "over-the-counter" [OTC]
2. imperfect competition [a.k.a., market power]
   - see e.g., Li and Schürhoff (2019) and Hendershott et al. (2019) for municipal bonds, Di Maggio, Kermani, and Song (2017) for corporate bonds, Atkeson, Eisfeldt, and Weill (2013), Begenau, Piazzesi, and Schneider (2015), and Siriwardane (2018) for credit and interest-rate derivatives
3. private information
   - see, e.g., Green, Hollifield and Schürhoff (2007) for municipal bonds, Hollifield, Neklyudov and Spatt (2017) for securitized products, Jiang and Sun (2015) for corporate bonds

A well-established result: these ingredients may **impede socially efficient trade**

Motivation

In this lecture, we will analyze how these frictions impede social efficiency of trade in **canonical environment** and how their impact can be reduced through:

- network of OTC intermediaries
- voluntary disclosure
- market design and other solutions [briefly, if time permits]

[Note: we will focus on actual bilateral interaction, rather than how traders meet, contrasting with extensive literature on search frictions in OTC markets]

Numerical Example

Bilateral transaction: owner/seller values (indivisible) asset at $\bar{c} < 1$ and prospective buyer values it at $v \sim U[1,2]$

- surplus from trade is always positive
- "efficient" trade yields total surplus: $E[v] - \bar{c} = 1.5 - \bar{c}$

Private information: buyer knows realization of v [i.e., own valuation] but seller does not know buyer's valuation

Classic monopoly pricing problem: seller quotes price that solves

$$\max_{p \in [1,2]} \Pi(p) = Pr(v \geq p)p + Pr(v < p)\bar{c} = (2-p)p + (p-1)\bar{c}$$

FOC: $p^* = 1 + \frac{\bar{c}}{2} \Rightarrow$ trade is efficient [i.e., $p^* = 1$] if and only if $\bar{c} \leq 0$

For example, if $\bar{c} = 0.5$:

- $p^* = 1.25$
- surplus is destroyed with probability 0.25 [inefficient screening]
- seller's profit: $0.75 \cdot (1.25 - 0.5) = 0.56$
- buyer's profit: $0.75 \cdot (1.625 - 1.25) = 0.28$

Numerical Example: Role Played by Market Power

To emphasize key role played by seller's market power, let's see what would have happened with 2 uninformed sellers instead of monopolist

- buyer observes both prices before deciding which seller to buy **one asset** from

Easy to show, by contradiction, that sellers cannot quote prices that generate strictly positive profits in equilibrium

- in efficient equilibrium, both sellers must quote $\bar{c}$

Moreover, for trade to be efficient, informed buyer must accept to pay $\bar{c}$ even when asset is least valuable [i.e., $v = 1$]

$\Rightarrow$ Trade is efficient if and only if $\bar{c} \leq 1$

- in contrast to $\bar{c} \leq 0$ with monopolist seller

[Note: actual monopoly is not needed for inefficient screening, but somewhat inelastic "residual" demand curve is – see Biais, Martimort, and Rochet 2000; Vives 2011]

Looking for Solutions

Case with competitive sellers suggests that one solution to inefficient trading is to **eliminate seller's market power**

But asset might be in scare supply + **uninformed seller does not want to give up market power** and agree to sell asset at efficient price $p \leq 1$ [even though it would increase total surplus from trade]

- more about optimal mechanisms later

Given vast empirical evidence of market power problems in OTC markets, we will treat allocation of bargaining power between agents as **primitive of our economy** and look for solutions to inefficient trading behaviors associated with it

- our insights will more generally extend to bilateral interactions in which **allocations of private information and market power are not perfectly aligned**

Generalized Environment

Bilateral transaction [i.e., classic monopoly pricing problem]

- **Prospective buyer:**
  - values asset ex post at v according to CDF $F(v)$ with full support on $[v_L, v_H]$
  - **private information:** knows true realization of v

- **Seller:**
  - values asset ex post at $c(v)$, where $c(v) < v$ and $c'(\cdot) \geq 0$
  - does not know v
  - **market power:** quotes a take-it-or-leave-it price for asset
    - Samuelson (1984): "optimal bargaining strategy of the uninformed player"
    - Viswanathan and Wang (2004): "very quick interactions"
    - Duffie (2012): "reputation for standing firm on its original quotes"

$\Rightarrow$ Trade is **socially efficient** if and only if buyer gets asset with probability 1

[Note: buyer/seller roles could be reversed without affecting our results]

Optimal Pricing Strategy

Seller quotes p to buyer, which buyer accepts if and only if: $v \geq p$

Seller's **expected payoff** from quoting p:

$$\begin{aligned} \Pi(p) &\equiv Pr(v \geq p)p + Pr(v < p)\mathbb{E}[c(v)|v < p] \\ &= [1 - F(p)]p + F(p)\mathbb{E}[c(v)|v < p] \end{aligned}$$

Seller's **marginal payoff** from increasing p:

$$\Pi'(p) = [1 - F(p)] - f(p)[p - c(p)]$$

$\Rightarrow$ Trade is efficient iff seller chooses $p^* = v_L$, i.e., trade occurs with prob. 1

- seller might however be tempted to quotes $p^* > v_L$ to **inefficiently screen** privately informed buyer

[Note: when indifferent, we assume agent picks strategy that maximizes social surplus in equilibrium]

Efficient Trade?

Assumption (# 1: Regularity Condition)

$H(v) \equiv \frac{f(v)}{1-F(v)}[v - c(v)]$ *is strictly increasing in* v *for* $v \in [v_L, v_H)$.

Why?

1. FOC pins down unique Nash equilibrium
2. standard assumption in auction theory [Myerson 1981]
3. satisfied with strictly increasing hazard rate $\frac{f(v)}{1-F(v)}$ and $c(v) = \bar{c}$, $c(v) = \beta v$, or $c(v) = v - \Delta$

$\Rightarrow$ **Trade is efficient** iff:

$$\Pi'(v_L) \leq 0$$

or equivalently

$$H(v_L) = f(v_L)[v_L - c(v_L)] \geq 1$$

Otherwise, trade breaks down with some probability and part of surplus is destroyed $\Rightarrow$ **inefficient screening arises when gains to trade are positive but small and seller's beliefs about v are dispersed**

Mechanism Design Approach?

Myerson and Satterthwaite (1983): "set of allocation mechanisms that are Bayesian **incentive compatible and individually rational**"

As alluded earlier, if uninformed trader could choose mechanism, (s)he would **quote take-it-or-leave-it price** to informed counterparty as in our model [Samuelson 1984; Biais and Mariotti 2005]

But what mechanism would **social planner** concerned with trade efficiency choose?

$\Rightarrow$ **Putting aside seller's bargaining power**, let's search for mechanisms [i.e., combination of asset allocation and monetary transfer rules] that implement efficient trade

- $q(\hat{v})$ denotes probability of asset being allocated to buyer and $t(\hat{v})$ denotes monetary transfer from buyer to seller when buyer's reported valuation is $\hat{v}$

Efficient Mechanisms

Since surplus from trade is always positive, efficient mechanism must feature $q(\hat{v}) = 1$ for $\forall \hat{v}$, which means that buyer's expected profit from reporting $\hat{v}$ is:

$$q(\hat{v})v - t(\hat{v}) = v - t(\hat{v})$$

$\Rightarrow$ If $q(\hat{v}) = 1$ for $\forall \hat{v}$, buyer always wants to report $\hat{v} = argmin_v t(v)$

- in incentive-compatible mechanism, we need $t(\hat{v}) = p$ [i.e., a constant transfer] to prevent buyer from misreporting

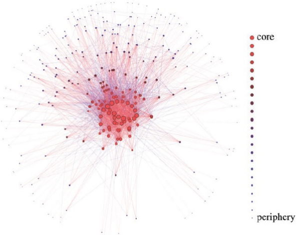
We now know that efficient mechanism must take the form: $(q(\hat{v}), t(\hat{v})) = (1, p)$ and all that is left to check is that there exists price p for which uninformed seller is willing to participate and informed buyer is willing to participate even if $v = v_L$

- seller's (PC) condition: $p \geq \mathbb{E}[c(v)]$
- buyer's (IC) condition: $p \leq v_L$
- such p exists whenever $\mathbb{E}[c(v)] \leq v_L$

To summarize: efficient bilateral mechanism exists iff $\mathbb{E}[c(v)] \leq v_L$
[will be useful later]

Looking for (Empirically Relevant) Solutions

Stylized fact about OTC trading:



[from Hollifield, Neklyudov, and Spatt 2017]

Could these layers of intermediation solve problem studied so far?

- Or will double marginalization make problem worse [as in Spengler 1950; Gofman 2014]?

Solution 1: Moderately Informed Intermediary

Consider involvement of **moderately informed** intermediary

- values asset ex post at $c(v)$, like seller [i.e., does not realize gains to trade]
- receives one of N possible signal realizations, each associated with conditional distribution $F_i(v)$, where $i \in \{1, 2, ...N\}$

Our focus: $F_i(v)$ is partition of $F(v)$ over $[\underline{v}_i, \overline{v}_i]$

Why?

- non-overlapping regions allow to focus on fully efficient trade
- following result will greatly simplify analysis:

Lemma (#1: Regularity Condition)

If Assumption 1 is satisfied under some distribution $F(\cdot)$, it is also satisfied under any truncated version of that distribution

[from Glode and Opp 2016]

Trading game at each stage:

- Current asset holder makes ultimatum offer to counterparty
- Trading network cannot be bypassed [i.e., sparsely connected network]

Moderately Informed Intermediary

Intermediated trade is efficient iff:

1. when owning asset, intermediary finds it optimal to quote price that is accepted by buyer with prob. 1, i.e.,

$$H_i(\underline{v}_i) = f_i(\underline{v}_i)[\underline{v}_i - c(\underline{v}_i)] \geq 1 \quad \text{for} \quad i \in \{1, 2, ..., N\}$$

2. given that, seller finds it optimal to quote price that is accepted by intermediary with prob. 1, i.e.,

$$p^* = v_L$$

By involving intermediary, we replaced 1 condition for efficient trade by $(N+1)$ conditions...

Numerical Example with Intermediary

Asset is worth $\bar{c} \leq 1$ to seller and $v \sim U[1,2]$ to buyer

Consider intermediary who knows whether $v \in [1, 1.67)$ or $v \in [1.67, 2]$

When holding asset, intermediary solves:

$$\max_{p \in [1,1.67)} \Pr(v \geq p | v < 1.67) p + \Pr(v < p | v < 1.67) \bar{c} = \left(\frac{1.67 - p}{0.67} \right) p + \left(\frac{p-1}{0.67} \right) \bar{c}$$

and:

$$\max_{p \in [1.67,2]} \Pr(v \geq p | v \geq 1.67) p + \Pr(v < p | v \geq 1.67) \bar{c} = \left(\frac{2 - p}{0.33} \right) p + \left(\frac{p-1.67}{0.33} \right) \bar{c}$$

Intermediary quotes efficient prices $p = 1$ when $v \in [1, 1.67)$ and $p = 1.67$ when $v \in [1.67, 2]$ iff:

$$\frac{1}{0.67} \cdot (1 - \bar{c}) \geq 1 \quad \text{and} \quad \frac{1}{0.33} \cdot (1.67 - \bar{c}) \geq 1$$

$\Rightarrow$ **Weaker** condition [i.e., $\bar{c} \leq 0.33$] than under direct trade [i.e., $\bar{c} \leq 0$] since partitions imply higher conditional hazard rate!

Numerical Example with Intermediary

Given that, seller considers quoting $p = 1$ or $p = 1.67$ to intermediary

Seller prefers to quote efficient price $p = 1$ iff:

$$1 \geq 0.33 \cdot 1.67 + 0.67 \cdot \bar{c}$$

$\Rightarrow$ **Weaker** condition [i.e., $\bar{c} \leq 0.67$] than under direct trade [i.e., $\bar{c} \leq 0$] since deviation to inefficient price needs to be much larger now!

Overall, intermediated trade is efficient iff $\bar{c} \leq 0.33$
$\Rightarrow$ If $\bar{c} \in (0, 0.33]$: **Trade is efficient only when moderately informed intermediary is involved!**

First General Result on Intermediation

Proposition (# 1: Moderately Informed Intermediary)

Let $\Omega^1(F)$ and $\Omega^0(F)$ denote the set of functions $c(\cdot)$ associated with efficient trade with and without an intermediary, respectively, for a given CDF $F(\cdot)$, under Assumption 1. If the intermediary's signal partitions the support of v into $N \geq 2$ subintervals of strictly positive measure, then the set of functions $c(\cdot)$ that allow for efficient trade is strictly larger with the intermediary, that is, $\Omega^0(F) \subset \Omega^1(F)$.

[from Glode and Opp 2016]

Sketch of proof: Let's all stare long enough at...

(i) intermediary's pricing tradeoff:

$$H_1(v_L) = \left[\frac{f(v_L)}{F(\overline{v}_1) - F(v_L)}\right][v_L - c(v_L)] > \left[\frac{f(v_L)}{1 - F(v_L)}\right][v_L - c(v_L)] = H(v_L)$$

(ii) seller's efficiency constraint:

$$v_L \geq [1 - F(\underline{v}_i)]\underline{v}_i + F(\underline{v}_i)\mathbb{E}[c(v)|v < \underline{v}_i] \qquad \text{for} \qquad \forall i \in \{2, ..., N+1\}$$

Multiple Intermediaries

Unlike most models of endogenous intermediation, ours provides explanation for the sequential involvement of **multiple** intermediaries

Intermediation Chain:

Firm → **Trader 1** → **Trader 2** → **Expert**

Consider involvement of M intermediaries who each receive different signals that partition domain $[v_L, v_H]$ into sub-intervals

Assumption (# 2: Nested Information Sets)

If intermediary $m < M$ knows that $v \in [\underline{v}_i^m, \overline{v}_i^m)$, then intermediary $(m+1)'s$ information partitions $[\underline{v}_i^m, \overline{v}_i^m)$ into at least three subintervals of strictly positive measure.

Tractability: ultimatum offers + nested information sets
$\Rightarrow$ unique subgame perfect Nash equilibrium [despite $M+1$ transactions among $M+2$ heterogeneously informed agents]

Second General Result on Intermediation

Proposition (#2: Intermediation Chains)

Let $\Omega^M(F)$ denote the set of functions $c(\cdot)$ associated with efficient trade in a chain of M intermediaries with information sets satisfying Assumption 2 for a given CDF $F(\cdot)$, under Assumption 1. There exists a set of $\tilde{M} \geq 1$ intermediaries who can be added to the chain such that the set of functions $c(\cdot)$ associated with efficient trade is strictly enlarged, that is, $\Omega^M(F) \subset \Omega^{M+\tilde{M}}(F)$.

[from Glode and Opp 2016]

Translation: if M intermediaries do not sustain efficient trade, $(M + \tilde{M})$ intermediaries might $\Rightarrow$ severe screening problems require **longer** intermediation chains

- consistent with empirical findings by Li and Schürhoff (2019), Di Maggio, Kermani, and Song (2017), and Hollifield, Neklyudov, and Spatt (2017)

Numerical Example with Intermediary

Asset is worth $\bar{c} \leq 1$ to seller and $v \sim U[1,2]$ to buyer

Intermediary 1 knows whether $v \in [1, 1.67)$ or $v \in [1.67, 2]$

$+$ intermediary 2 knows whether $v \in [1, 1.33)$, $v \in [133, 1.67)$ or $v \in [1.67, 2]$

Usual derivations allow us to show that trade through this "intermediation chain" is efficient iff $\bar{c} \leq 0.67$

$\Rightarrow$ If $\bar{c} \in (0.33, 0.67]$, **trade is efficient only when both moderately informed intermediaries are involved!**

Robustness

Our main result: chains of heterogeneously informed intermediaries can reduce monopolistic pricing incentives, thereby facilitating efficient trade

- Tractability: unique equilibrium solution

In working paper version: we revisited parameterized example and showed how our main result extends to alternative informational settings with

1. informed seller (responder) and uninformed buyer (proposer) [thereby, allowing for short selling]
2. two-sided asymmetric information [thereby, allowing for signaling]

How Far Can This Solution Take Us?

Proposition (#3: "Long" Intermediation Chains)

A chain implementation of efficient trade exists iff $\mathbb{E}[c(v)] < v_L$*. Specifically, there exists a partition rule and a threshold* M^* *such that the involvement of* $M \geq M^*$ *intermediaries with information sets satisfying this partition rule sustains efficient trade.*

[from Glode, Opp and Zhang 2019]

Intuition: intermediary 1 knows whether $v \in [v_L, v_H - \epsilon)$ or $[v_H - \epsilon, v_H]$; intermediary 2 knows whether $v \in [v_L, v_H - 2\epsilon)$, $[v_H - 2\epsilon, v_H - \epsilon)$, or $[v_H - \epsilon, v_H]$; $(...)$ intermediary m knows whether $v \in [v_L, v_H - m\epsilon)$, $\cdots$, $[v_L - 2\epsilon, v_H - \epsilon)$, or $[v_H - \epsilon, v_H]$; etc.

$\Rightarrow$ In canonical setting, **long chains of heterogeneously informed intermediaries are as good at delivering efficient trade as optimal bilateral mechanisms or introducing competitive sellers** [except for knife-edge case]

Implications on Intermediation

Our main insight: in classic monopoly pricing problem, **layering information asymmetry over sequential transactions** can facilitate efficient trade

Positive implications:

- observing longer intermediation chains for municipal bonds without credit ratings [Li and Schürhoff 2019], corporate bonds traded in periods of high uncertainty [Di Maggio, Kermani, and Song 2017], and securitized products traded among heterogenously informed agents [Hollifield, Neklyudov, and Spatt 2017] is consistent with our story

Normative implications:

- while many empirical papers document the increasing complexity of OTC trading networks [and intermediation sector in general], our work shows how **(long) chains of heterogeneously informed intermediaries represent decentralized solutions** to inefficiencies associated with market power and asymmetric information

Solution 2: Voluntary Disclosure

Taking a step back [i.e., forgetting about intermediaries]...

Why would privately informed agent [e.g., buyer in our setup] let private information impede trade in first place?

- empirical evidence consistent with information sharing among traders/dealers [Boyarchenko, Lucca and Veldkamp 2016; Di Maggio et al. 2018]

What incentives does informed agent have to **share private information** with counterparty endowed with **market power** prior to bilateral transaction?

- classic problem in economics [our general environment] + information design

We will model a "persuasion" game as opposed to a "cheap talk" game

- disclosure is **ex post verifiable** [see Milgrom 2008 for survey], i.e., informed agent does not have to share info, but info shared must be truthful [e.g., "hard" financial data]

Market Power Matters [Again!]

Famous result in persuasion games:

- unlike in our environment, assume all traders take price as given [Milgrom 1981] or informed agent is monopolist [Grossman 1981]
  $\Rightarrow$ **full disclosure is optimal** [a.k.a., unraveling]

- intuition 1 [Milgrom 1981]:
  - informed buyer can share signal s and competitive sellers will offer $p = \mathbb{E}[c(v)|s]$ in exchange for asset
  - suppose s is $v \leq x$ [recall: ex post verifiability] $\Rightarrow$ buyer's profit is $v - \mathbb{E}[c(v)|v \leq x]$
  - informed buyer is better off picking lowest x such $v \leq x$, i.e., $x = v$

- intuition 2 [Grossman 1981]:
  - suppose informed buyer always discloses v and quotes $p = c(v)$
  - buyer's ex ante profit is $\mathbb{E}[v - c(v)]$
  - like with competitive sellers, informed buyer extracts full surplus

Market Power Matters [Again!]

Famous result in persuasion games:

- unlike in our environment, assume all traders take price as given [Milgrom 1981] or informed agent is monopolist [Grossman 1981]
  $\Rightarrow$ **full disclosure is optimal** [a.k.a., unraveling]

- **in contrast**: in our environment agent with market power screens privately informed counterparty [i.e., classic monopoly pricing problem]
  - relevance? multitude of scenarios where market power and private information are **(partially) separated** [e.g., real estate, OTC trading, supply chains]

  $\Rightarrow$ **full disclosure is very bad idea!** [why?]

Benefits of Disclosure?

In our environment, since buyer's private information results in seller "screening" him/her, could buyer do better by **disclosing some information** prior to trading?

- hint 1: in earlier example with $\bar{c} = 0.5$, shouldn't buyer inform seller if $v < 1.25$?
- hint 2: if buyer discloses v, seller quotes $p^* = v$ and buyer makes no profit

For now: suppose buyer must design disclosure plan **prior** to acquiring private information and commit to not manipulating the signal later [as Bayesian persuasion literature and most models of information design]

- this timeline eliminates signaling concerns [we will relax this later]

As in Grossman (1981), Milgrom (1981), Shin (2003), and many others, we restrict our attention to **"ex post verifiable"** disclosures/signals, thereby eliminating lying and use of unbiased noise or randomizations:

Definition (#1)

Signal s whose realization belongs to set S is called **"ex post verifiable"** if it can be represented by function $D : [v_L, v_H] \to S$ such that $D^{-1}(s) \equiv \{v : D(v) = s\} \in \mathcal{B}([v_L, v_H])$, where $\mathcal{B}([v_L, v_H])$ denotes Borel algebra on $[v_L, v_H]$.

Numerical Example with Disclosure

Asset is worth $\bar{c} = 0.5$ to seller and $v \sim U[1,2]$ to buyer

- without disclosure, seller quotes $p^* = 1.25$ and buyer collects profit 0.28
- with full disclosure, seller quotes $p^* = v$ and buyer makes no profit

Suppose buyer designs disclosure plan informing seller whether $v \in [1, 1.25)$ or $v \in [1.25, 2]$

If seller learns that $v \geq 1.25$, his/her optimal price solves:

$$\max_{p \in [1.25,2]} \Pr\left(v \geq p | v \geq 1.25\right) p + \Pr\left(v < p | v \geq 1.25\right) \bar{c}$$

$\Rightarrow p^* = 1.25$; conditional on signal, trade is efficient

- Lemma 1 in Glode, Opp, and Zhang (2018) generalizes this property

If seller instead learns that $v < 1.25$, his/her optimal price solves:

$$\max_{p \in [1,1.25)} \Pr\left(v \geq p | v < 1.25\right) p + \Pr\left(v < p | v < 1.25\right) \bar{c}$$

$\Rightarrow p^* = 1$; conditional on signal, trade is efficient

Buyer's expected profit: $\underbrace{0.75 \cdot (1.625 - 1.25)}_{\text{profit w/o disclosure}} + \underbrace{0.25 \cdot (1.125 - 1)}_{\text{gain from disclosure}} = 0.31$

First General Result on Voluntary Disclosure

When bilateral trade is inefficient without disclosure...

Proposition (#4: Properties of Voluntary Disclosure Plans)

If buyer can commit to any disclosure plan that sends ex post verifiable signals to seller, (s)he designs **partial** *disclosure plan that yields* **socially efficient** *trade.*

[from Glode, Opp and Zhang 2018]

Intuition:

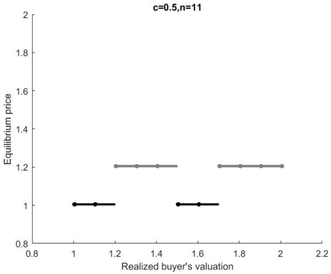
1. as in earlier example, for any disclosure plan $D(v)$ which does not implement efficient trade we can construct alternative disclosure plan $\tilde{D}(v)$ that strictly improves buyer's profit **and** social efficiency of trade
   $\Rightarrow$ **optimal disclosure must result in efficient trade**

2. full disclosure yields zero profit and is dominated by no disclosure
   $\Rightarrow$ **optimal disclosure must be partial**

Optimal Disclosure in Numerical Example

While we can intuitively derive general properties of optimal disclosure plan, fully characterizing it boils down to a **non-convex functional optimization** problem...

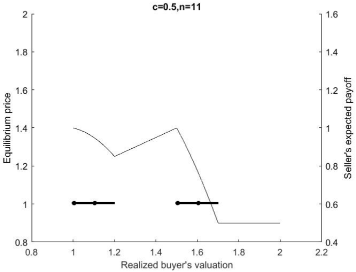
Solving numerically for optimal disclosure plan in numerical example:



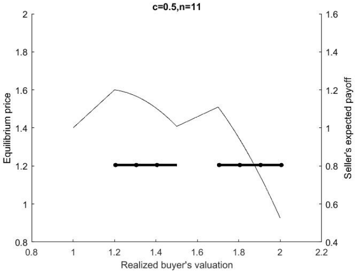
- low [dark] signal: seller quotes $p^* = 1$ and buyer always accepts
- high [pale] signal: seller quotes $p^* = 1.2$ and buyer always accepts
- seller's profit: $0.36 \cdot (1 - 0.5) + 0.64 \cdot (1.2 - 0.5) = 0.63$
- buyer's profit: $0.36 \cdot (1.3 - 1) + 0.64 \cdot (1.6 - 1.2) = 0.37$

Optimal Disclosure in Numerical Example

Seller's expected payoff for various price quotes under optimal disclosure plan:



(a) low signal



(b) high signal

⇒ Optimal disclosure plan pools regions of v **up until seller becomes indifferent**, after receiving low signal, between quoting efficient price $p = 1$ and inefficient price $p = 1.5$

- otherwise, buyer should pool larger region of v into low signal to increase probability of getting asset at lowest price possible [i.e., $p = 1$]

Designing Optimal Disclosure Plan

Tradeoff: buyer may benefit from **pooling realizations or intervals** that are far from each other, but doing so increases seller's **incentives to quote high, inefficient prices**

Proposition (#5: Binding Efficiency Constraints)

Under an optimal disclosure plan with n *possible signal realizations for which* $v > c(v)$*, the efficiency constraints associated with the* $(n-1)$ *lowest signal realizations are binding.*

[from Glode, Opp and Zhang 2018]

Definition (#2)

The constraint that trade has to be efficient conditional on a signal $s \in S$ generated by a disclosure function $D(\cdot)$ is said to be "binding" if $\Pi'_s(\inf\{D^{-1}(s)\}) = 0$, or if there exists a price $\bar{p} \in D^{-1}(s)$ such that $\bar{p} \neq \inf\{D^{-1}(s)\}$, and $\Pi_s(\inf\{D^{-1}(s)\}) = \Pi_s(\bar{p})$, where $\Pi_s(p)$ denotes the seller's expected payoff from quoting a price p after receiving a signal s.

Monotone Disclosure Plans

To learn more about tradeoffs associated with designing $D(\cdot)$, we impose:

Assumption (#3)

Disclosure plans $D(v)$ are restricted to be monotone in v.

[standard arguments of manipulation proofing would carry over to our environment]

Buyer's optimization problem can be recast as finding partition cutoffs $(v_2, ..., v_n)$ that minimize expected price for the asset:

$$\sum_{s=1}^{n} \left[F(v_{s+1}) - F(v_s)\right] v_s,$$

subject to a set of efficiency constraints: $H_s(v_s) \geq 1 \qquad \forall s \in \{1, ..., n\}$

Monotone Disclosure Plans

Recall that efficiency constraints relate to **seller's screening incentives** and can be rewritten as:

$$f(v_s)[v_s - c(v_s)] \geq F(v_{s+1}) - F(v_s)$$

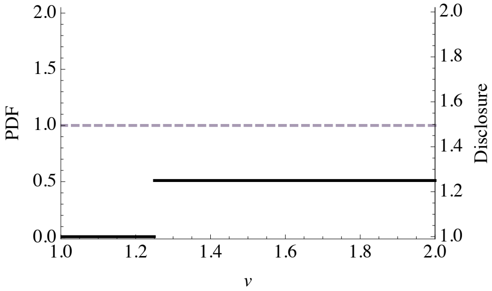
$\Rightarrow$ **Shape of optimal disclosure plan and its precision in different parts of the support of v intimately linked to seller's screening incentives**

- smaller gains to trade $v_s - c(v_s)$ $\Rightarrow$ trade breakdowns are less costly to seller
- lower density $f(v_s)$ $\Rightarrow$ price increases result in smaller drop in probability of trade
- buyer must design more precise disclosure [i.e., smaller $F(v_{s+1}) - F(v_s)$] to prevent screening

Let's look at optimal **monotone** disclosure plans under various parameterizations...

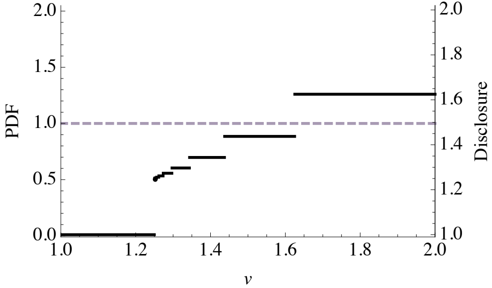
Monotone Disclosure Plan in Earlier Numerical Example

Asset is worth $\bar{c} = 0.5$ to seller and $v \sim U[1,2]$ to buyer



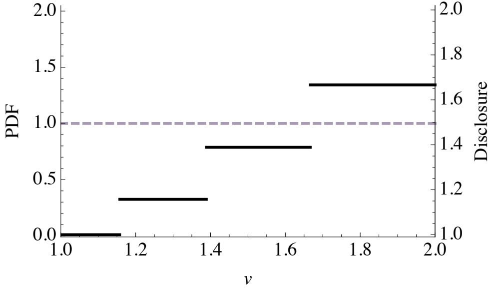
Lower Gains to Trade

Asset is worth $\bar{c} = 1.25$ to seller and $v \sim U[1,2]$ to buyer



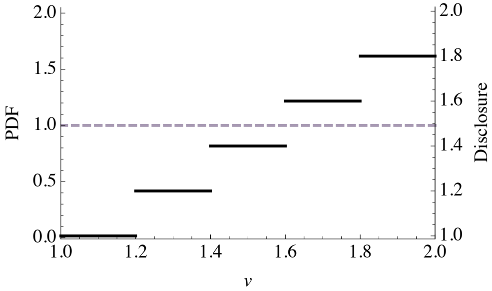
Proportional Gains to Trade

Asset is worth $c(v) = 0.8 \cdot v$ to seller and $v \sim U[1, 2]$ to buyer



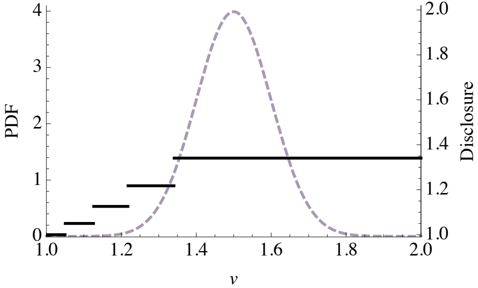
Constant Gains to Trade

Asset is worth $c(v) = v - 0.20$ to seller and $v \sim U[1,2]$ to buyer



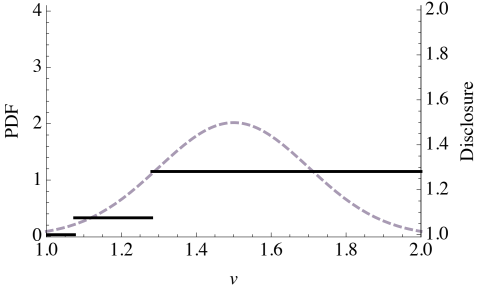
Truncated Normal Distribution

Asset is worth $\bar{c} = 0.5$ to seller and $v \sim N(1.5, 0.1)$ to buyer



Fatter Tails

Asset is worth $\bar{c} = 0.5$ to seller and $v \sim N(1.5, 0.2)$ to buyer



Interim Disclosure

What if disclosure is **chosen after** buyer obtains private information?

New timeline:

1. buyer privately observes v
2. buyer designs ex post verifiable signal $D(v)$ to send to seller
3. seller quotes price
4. buyer accepts or rejects trade

Definition (#3)

A $(D(\cdot), \mu(\cdot), p(\cdot))$ profile forms a perfect Bayesian equilibrium of the interim disclosure game if:

1. For every possible signal s, $p(s)$ solves $\max_p\{\Pi_s(p)\}$, where $\Pi_s(p)$ denotes the seller's expected profit if he quotes a price p and the buyer's valuation is drawn from $\mu(s)$.
2. For every $v \in [v_L, v_H]$, $D(v)$ solves $\max_s\{\max[v - p(s), 0]\}$, where $v \in D(v)$.
3. For every s in the range of D (i.e., every Borel set s that can be disclosed in equilibrium), the seller's belief $\mu(s)$ is obtained by applying Bayes' rule given the particular signal s.

Interim Disclosure

Drawback of interim disclosure: since beliefs are unrestricted following off-equilibrium deviations, seller's market power allows to drive buyer's information rents to zero following any off-equilibrium deviation in disclosure

- if for any s not in range of $D(\cdot)$ [i.e., whenever s is an off-equilibrium signal], belief $\mu(s)$ assigns probability 1 to type $\bar{v}(s)$, where $\bar{v}(s) \equiv \max s$

$\Rightarrow$ **Equilibrium multiplicity!** [Perez-Richet 2014]

- equilibria with no disclosure exist
- equilibria with partial disclosure exist
- equilibria with full disclosure exist

We restrict our attention to set of equilibria that survive either of these two standard refinements:

- set of equilibria that are **not dominated among buyer types** [in the Pareto sense] by another equilibrium based on their interim payoffs [as in Riley 1979]
- set of equilibria that survive Grossman-Perry-Farrell refinement, thereby eliminating equilibria with **off-equilibrium beliefs that are deemed unreasonable** given agents' incentives to deviate from equilibrium strategies

Main Results with Interim Disclosure

Proposition (#6: Properties of Interim Disclosure Plans)

In any buyer-preferred equilibrium or Grossman-Perry-Farrell equilibrium of the interim disclosure game, the buyer's optimal disclosure is partial and yields socially efficient trade.

[from Glode, Opp and Zhang 2018]

Proposition (#7: Ex Ante vs. Interim)

An equilibrium disclosure plan of the ex ante disclosure game can be sustained in both a buyer-preferred equilibrium and a Grossman-Perry-Farrell equilibrium of the interim disclosure game.

[from Glode, Opp and Zhang 2018]

Economic arguments are similar in interim vs. ex ante cases: buyer "prefers" to share info than be quoted a screening price that results in no trade!

Implications on Disclosure

Our main insight: in classic monopoly pricing problem, informed agent is **privately incentivized** to design partial disclosure plan that yields **socially efficient** trade in equilibrium

- disclosures are restricted to truthful, ex post verifiable signals
- information rents only come from upcoming bilateral transaction

Positive implications:

- **type of private information** [hard vs. soft, verifiable vs. not, specific to transaction vs. generally valuable] and **enforceability of truthfulness** [regulatory and legal environments] greatly matter for determining extent to which it impedes efficient trade

Normative implications:

- in many instances, regulators or courts do not need to mandate what information traders must disclose nor do they need to produce additional information for uninformed market participants
    - as long as **truthfulness of disclosures is enforced** by disciplining traders who send signals that ex post prove to violate their own disclosure standards, traders may have incentives to **share information** in ways that **maximize social surplus**

Other Solutions?

Overarching theme: mechanisms that re-shape price-quantity tradeoff [i.e., $H(\cdot)$ function] can contribute to improving trade efficiency in OTC markets

- sequential trading among heterogeneously informed agents
- partial disclosure of private information

Any other **empirically relevant mechanisms** that re-shape this tradeoff?

- **market structure:** allowing to access more buyers by centralizing trade $\Rightarrow$ screening incentives strengthen $\Rightarrow$ lower efficiency of trade [thereby reducing information gathering by buyers; Glode and Opp 2019]

- **security design:** pooling assets $\Rightarrow$ screening incentives strengthen $\Rightarrow$ lower efficiency of trade [contrasting with DeMarzo 2005, which features competitive environment; Glode, Opp and Sverchkov 2019]

- any other ideas? [could lead to good job market paper!]

To Recap

Most (financial) assets are traded in **over-the-counter** markets

OTC transactions typically feature:

- **bilateral interactions**
- **market power**
- **private information**

These frictions are easily captured by standard model of **monopoly pricing**

Behaviors we observe in reality [and in data] appear consistent with trying to reduce impact of these frictions on efficiency of OTC trade [intermediation chains, voluntary disclosure, decentralization, security design, etc.]

- more work is needed to understand facts documented by quickly expanding empirical literature on OTC markets [e.g., Li and Schürhoff 2019; Hendershott et al. 2019; Di Maggio, Kermani, and Song 2017; Hollifield, Neklyudov and Spatt 2017; Begenau, Piazzesi, and Schneider 2015; Jiang and Sun 2015; Green, Hollifield and Schürhoff 2007, just to name a few]